COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

February 19, 1958

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

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D.1.7.

MEMO TO: D. V. Terrell
Director of Research

The attached report, "Comparative Laboratory Evaluation and Field Observations of a Modified Class I Base" was prepared as the result of observations made during the past construction season on several initial treatments. Comparative laboratory tests on Class I Base, Class I Binder, and Modified Class I base were reported to the Research Committee during the March 22, 1957 meeting. On the basis of these tests it was decided to construct two projects and observe the new base material on the road.

After one of the projects was completed, the other under construction, and the material appeared to be satisfactory for the proposed use, the Department decided to proceed with additional projects using the modified base as an initial treatment. Observations were not made on all of these projects but sufficient coverage was given to adequately report their performance.

Mr. Strunk's report covers both the initial laboratory investigation and the field installations. It appears that the grading selected for the modified base is quite satisfactory for initial treatment work and is better than the Standard Class I Base for this use.

This material might well be considered for a single type to be used as base or binder courses for high type pavements, thus eliminating any further need of differentiation between base and binder courses.

W. B. Drake
Associate Director of Research

WBD:dl
cc: Research Committee Members
J. C. Cobb (3)

Commonwealth of Kentucky
Department of Highways

COMPARATIVE LABORATORY EVALUATION AND FIELD OBSERVATIONS OF A MODIFIED CLASS I BASE

by

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INTRODUCTION

A number of materials and methods have been used in the continuing search for a satisfactory initial bituminous treatment. Towards this end, three traffic bound roads were given initial treatment,in the summer of 1956, with three inches of Kentucky's Standard Class I Base mixture. The large size coarse aggregate -- either No. 36 or No. 48 stone -- in this mixture made the material difficult to work, however, and caused severe segregation during handling. Although a well integrated mixture of the type could have been compacted to about eight percent voids, the excessive segregation left many areas of the pavement very open. It was believed, therefore, that any initial treatment with this material would have to be sealed in order to prevent entry of water.

During the winter of 1956-57, attention was directed to a new mixture, consisting of No. 6 stone and crushed limestone sand, which might combine the desireable features of both Class I Base and Class I Binder, permitting it to serve either as a high-type base or as a satisfactory initial treatment. After some preliminary work by the Division of Materials on the aggregate combinations, the Division of Research was asked to make a laboratory evaluation comparing the Standard Class I Base, the Standard Class I Binder, and the new mixture -- herinafter referred to as "modified Class I Base". An oral report on these evaluations was made at the March 1957 meeting of the Research Committee, and a memorandum report was submitted in July 1957. Following these favorable reports on laboratory testing and the successful construction of three trial roads, the modified Class I Base was used for initial treatment on approximately forty roads in 35 counties during the 1957 construction season.

This report presents the findings from the laboratory evaluation, the three trial roads, and the three roads given initial treatment of Standard Class I Base in 1956. It is felt that study of these findings clearly establishes the reliability of the modified Class I Base when properly supported.

LABORATORY TESTING

Prior to this study the Division of Materials established a combination of 65 percent No. 6 stone and 35 percent Class I limestone sand as probably the best for use in the modified Class I Base mixture. The gradation limits of this combination are plotted in Figure 1, below, together with the specification limits for Standard Class I Binder and Class I Base. The major difference among the three gradations is in the top sizes of the aggregates, which are one inch for the binder, 1.5 inches for the modified base, and 2.5 inches for the standard base.

The relatively large aggregate sizes required the use of specimens with a diameter of at least six inches for making valid comparison of the three mixes. Accordingly, the samples of each mix were compacted into molds six inches in diameter and twelve inches high. These specimens, shown in Figure 2, were compacted in four lifts of three

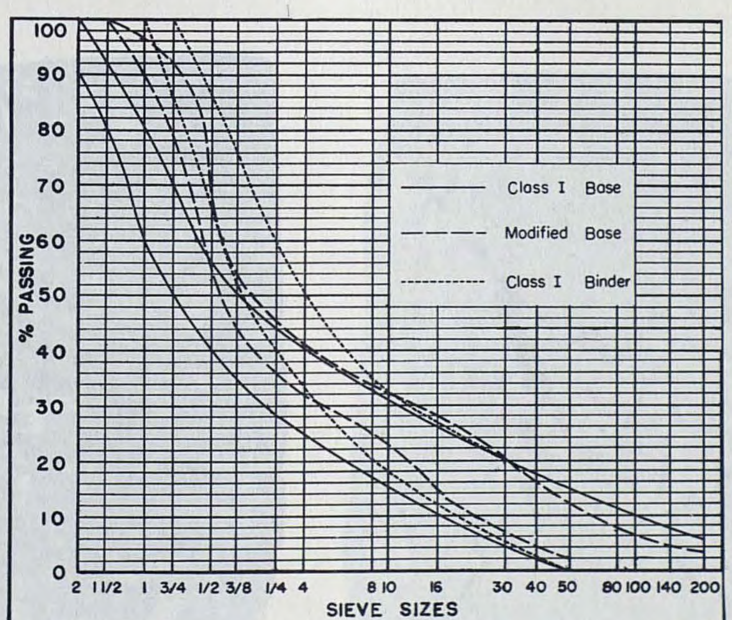


Fig. 1: Limits for the Three Gradations Tested

inches, each lift receiving fifty blows of the Marshall Hammer distributed evenly over the surface. For further compaction, a static load of 1000 psi was applied to each, held for two minutes and released. Then, after cooling, the specimens were pushed from the molds and allowed to cure for two weeks at room temperature.

Since properties contributed by the aggregates were to be of primary importance in the tests, a triaxial method of testing was chosen, and the pressure cell shown in Figure 3 was designed and fabricated specifically for testing specimens of the size used. Half of the specimens were tested in unconfined compression and the remaining half were tested in the pressure cell under 20 psi lateral pressure. Angles of internal friction and cohesion were obtained from graphical solution (Mohr Circles) of the Coulomb equation, $s = c + \sigma \tan \phi$ where s = shearing strength, c = cohesion, σ = normal pressure on the plane of failure and ϕ = angle of internal friction. Specimens were deformed at a constant rate of .02 inches per minute; deformation and time were recorded for each 500-lb. increment of load. The rather slow rate of deformation was used in an effort to minimize the effect of the asphalt's resistance to rapid deformation, since the testing was done at room temperature. Most failures were of the diagonal plane (See Fig. 4) or shear-cone type.

Fig. 4: Typical Failures of Test Specimens

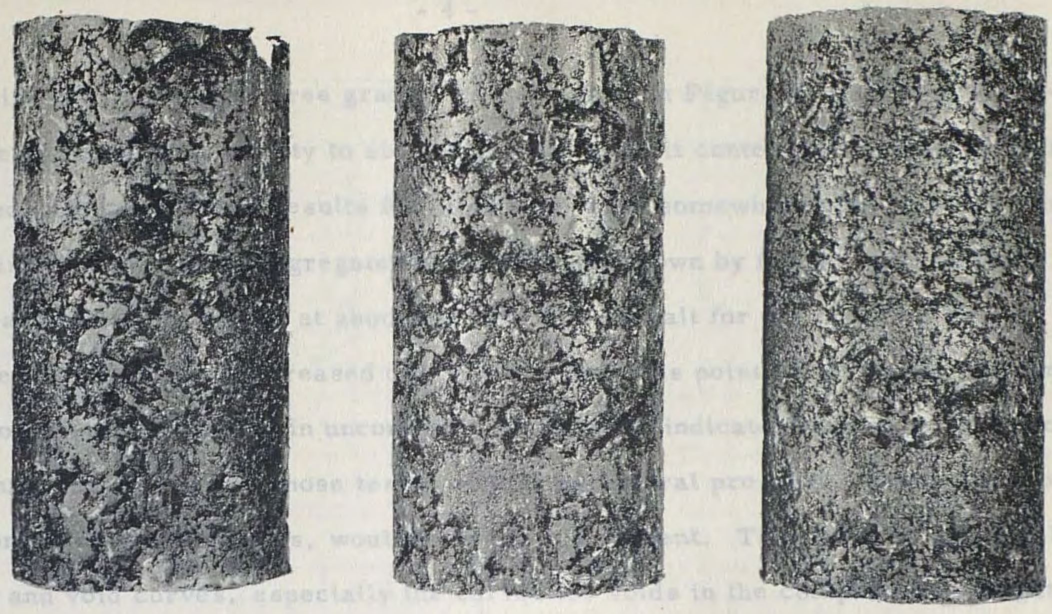


Fig. 2: Specimens used in Testing. Left to right: base, modified base, binder.

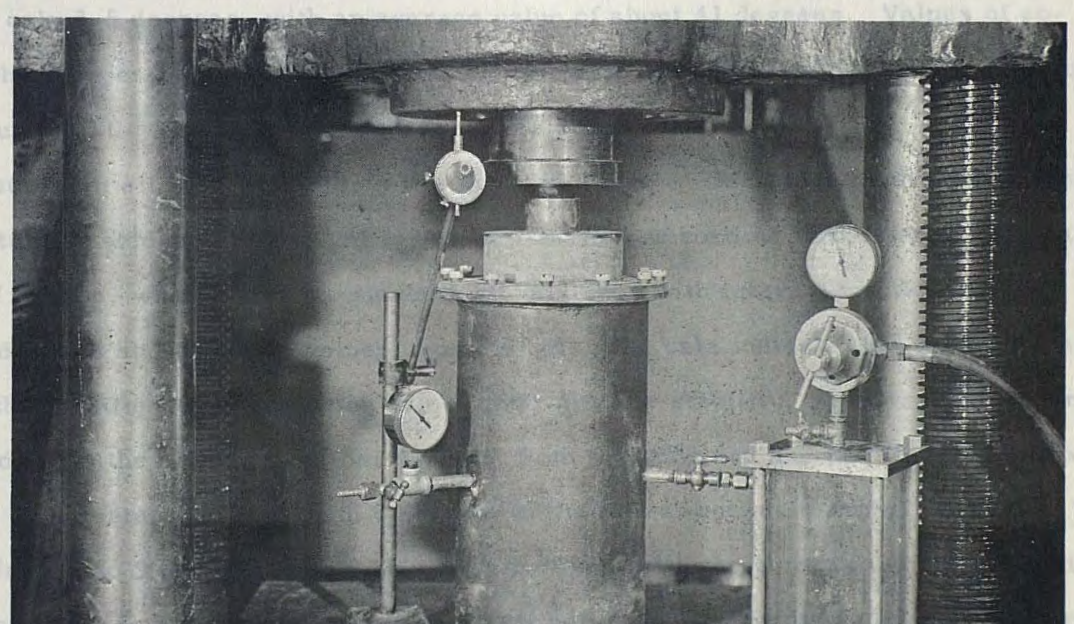


Fig. 3: Triaxial Compression Cell, in Operation

Design curves for the three gradations are shown in Figure 5. Unit weight curves indicate an increasing density to about 5 percent asphalt content for both the standard and modified base mixtures. Results for the binder were somewhat erratic, with no indicated optimum. Maximum aggregate compaction, as shown by fewest voids in the compacted aggregate, occurred at about 4.75 percent asphalt for the modified base. Voids in the base gradation decreased only slightly past this point. Curves for unit stress at failure for specimens tested in unconfined compression indicate a somewhat lower optimum asphalt content than do those tested with 20 psi lateral pressure. Optimum asphalt content, considering both curves, would be about 4.7 percent. This value is verified by the density and void curves, especially the curves for voids in the compacted aggregate.

Stress-strain curves (Fig. 6) were also plotted for mixtures with 4.5 and 5.0 percent asphalt content. There were no differences between these curves that could be attributed to the aggregate gradation.

At optimum asphalt content, the angle of internal friction for the three gradations varied by only 2.5 degrees, with an average value of about 41 degrees. Values of cohesion, which depend largely on the asphalt, were also quite similar, the average value being about 30 psi. Figure 7 shows these values graphically.

Data from all laboratory tests are given in Table 1. Mixtures made with any of the gradations tested would be regarded as satisfactory according to the Smith Triaxial Method of Design, which rates as adequate all mixtures with internal friction angles above 25 degrees and cohesion values about 15 psi. The data indicate that for all asphalt contents the modified base gradation has slightly greater stability, greater density, and fewer voids than the other gradations tested. Both the standard and modified base mixtures had void contents of less than 8 percent in the mix at optimum asphalt content. Void contents from 5 to 9 percent should be used for design with the compactive effort applied.

Following is a proposed gradation specification for the modified base. This gradation, illustrated graphically in Figure 8, contains all possible variations of the 65-35 combination.

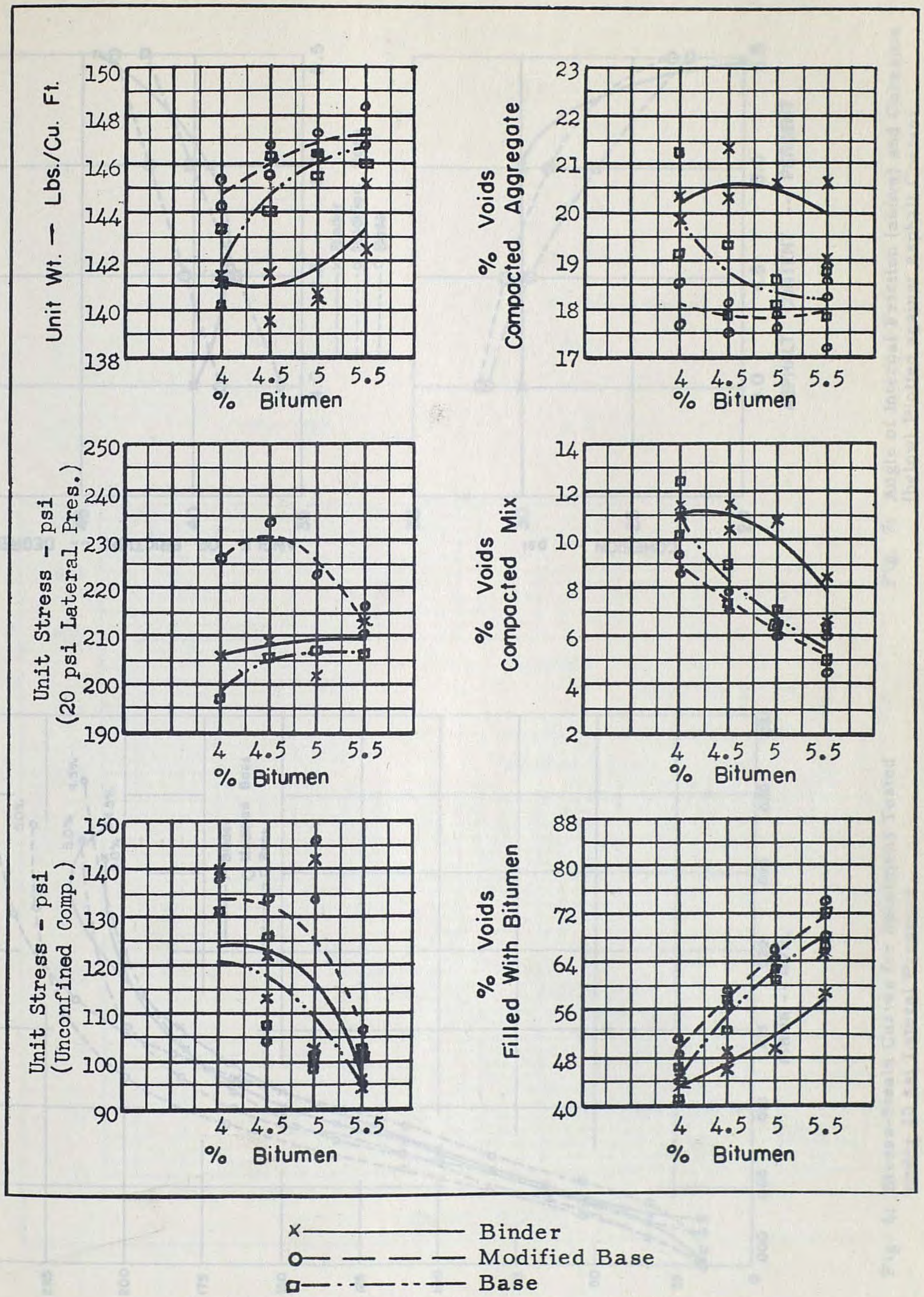


Fig. 5: Results of Tests on Specimens of the Three Gradations

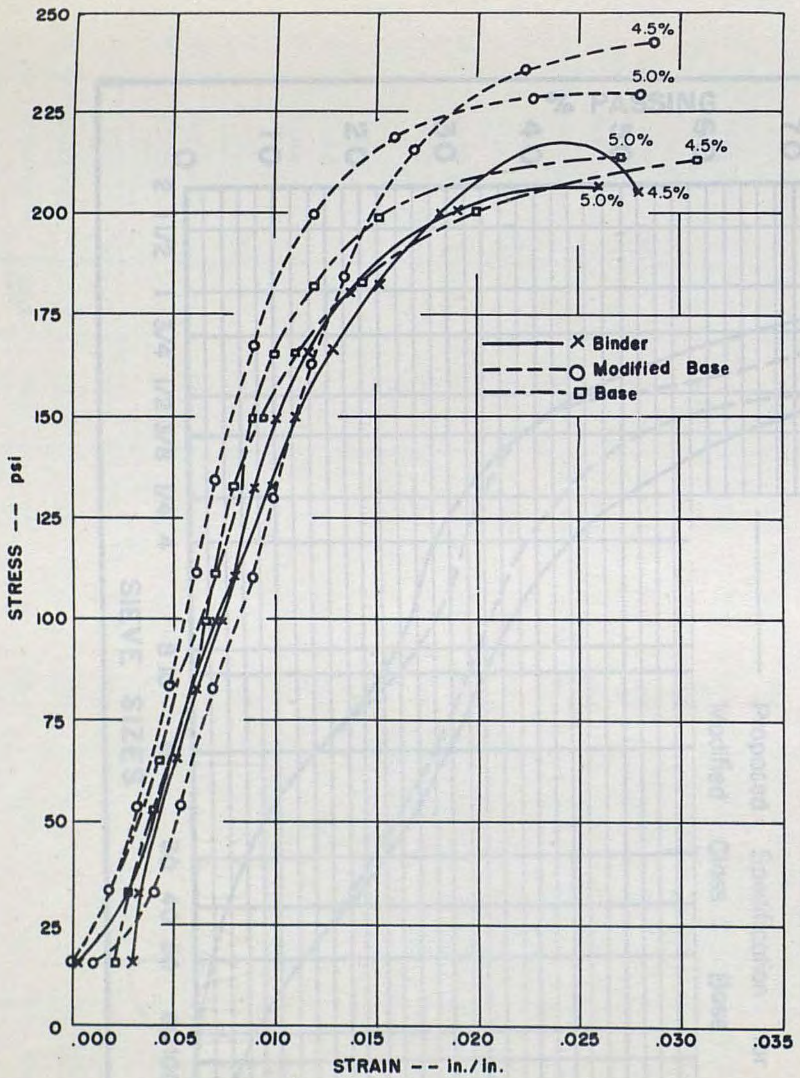


Fig. 6: Stress-Strain Curves for Specimens Tested under 20 psi Lateral Pressure

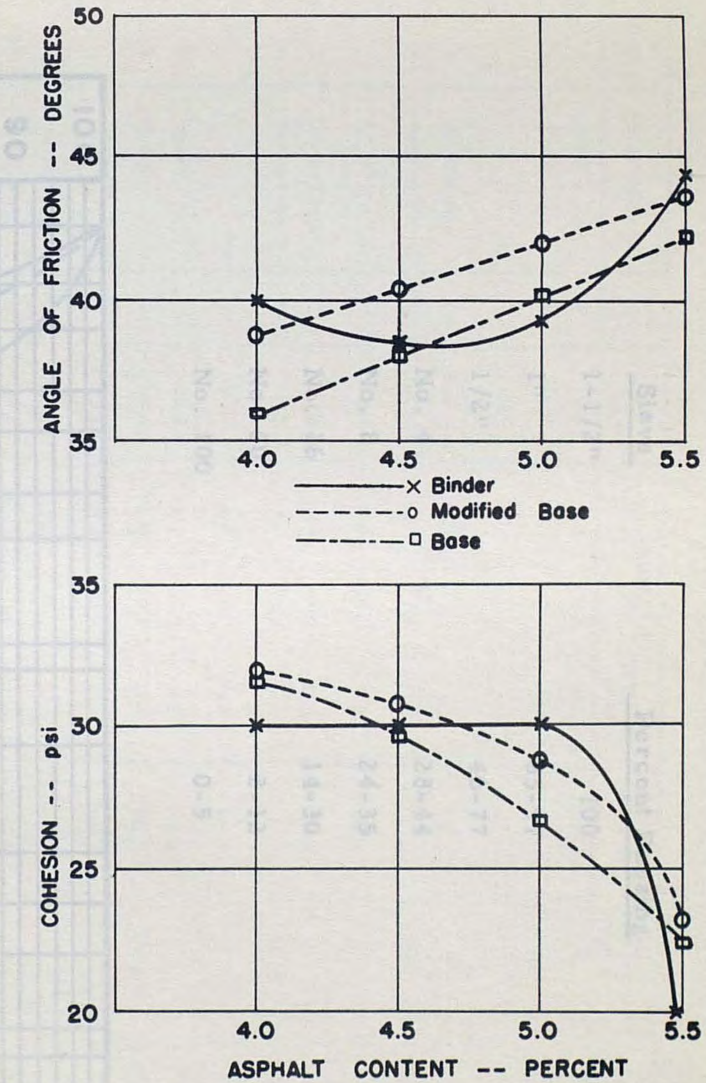


Fig. 7: Angle of Internal Friction (above) and Cohesion (below) Plotted against Asphalt Content

Sieve	Percent Passing
1-1/2"	100
1"	85-97
1/2"	46-77
No. 4	28-44
No. 8	24-35
No. 16	14-30
No. 50	2-12
No. 100	0-5

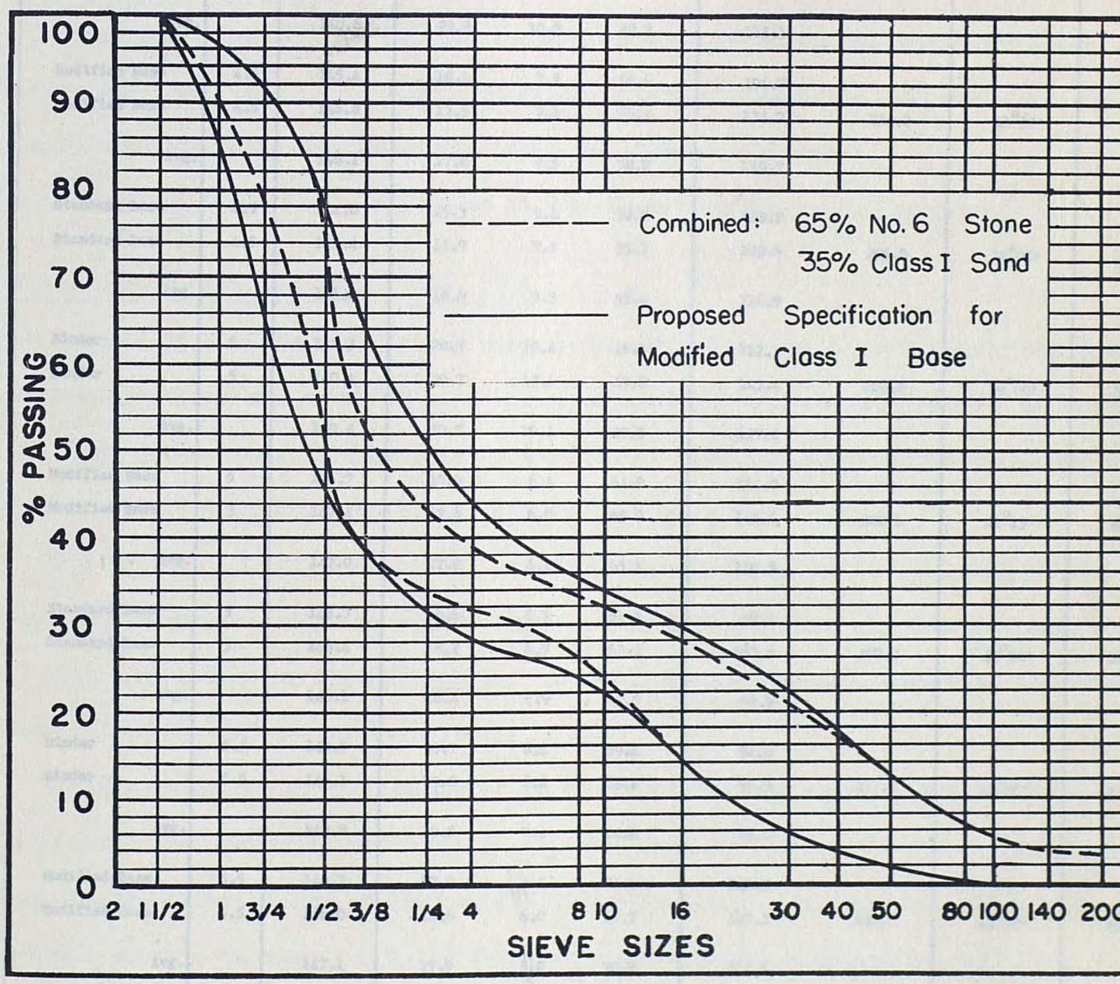


Fig. 8: Proposed Gradation Specification for Modified Class I Base

TABLE I

SUMMARY OF DATA FROM LABORATORY TEST SAMPLES

Sample No.	Sample Designation	Asph. Cont. %	Unit Wt. lb./cu.ft.	Per Cent Voids Agg. Only	Mix	Filled with Asphalt	Compressive Stress Unconfined	20 psi. Restraint	Angle of Friction	Apparent Cohesion psi.
1	Binder	4	141.7	19.9	11.0	44.7	140.2			
2	Binder	4	141.0	20.3	11.4	43.8		205.9	$39^{\circ}30'$	30.0
	Avg.		141.3	20.1	11.2	44.3	140.2			
3	Modified Base	4	144.1	18.5	9.4	49.2	138.1			
4	Modified Base	4	145.3	17.7	8.6	51.4		227.1	$38^{\circ}45'$	32.0
	Avg.		144.7	18.1	9.0	50.3	138.1			
5	Standard Base	4	143.3	19.2	10.2	46.9	131.7			
6	Standard Base	4	140.1	21.3	12.5	41.3		197.7	$35^{\circ}45'$	31.5
	Avg.		141.7	20.2	11.3	44.1	131.7			
7	Binder	4.5	141.6	20.3	10.3	49.3	113.9			
8	Binder	4.5	139.6	21.4	11.5	46.3	122.2	209.1	$38^{\circ}30'$	30.0
	Avg.		140.6	20.8	10.9	47.8	118.1			
9	Modified Base	4.5	145.4	18.2	7.9	56.6	104.7			
10	Modified Base	4.5	146.8	17.5	7.1	59.4	134.7	234.2	$41^{\circ}30'$	30.5
	Avg.		146.1	17.8	7.5	58.0	119.7			
11	Standard Base	4.5	144.0	19.3	9.1	52.8	108.2			
12	Standard Base	4.5	146.4	17.9	7.5	58.1	125.6	205.2	$38^{\circ}00'$	29.5
	Avg.		145.2	18.6	8.3	55.4	116.9			
13	Binder	5	140.3	20.7	10.4	49.8	112.3			
14	Binder	5	140.4	20.7	10.4	49.8	143.4	200.8	$39^{\circ}00'$	30.0
	Avg.		140.4	20.7	10.4	49.8	127.8			
15	Modified Base	5	146.7	17.9	6.4	64.2	134.0			
16	Modified Base	5	147.4	17.6	6.0	65.9	146.5	222.1	$41^{\circ}15'$	29.0
	Avg.		147.0	17.8	6.2	65.1	140.3			
17	Standard Base	5	145.7	18.6	7.1	61.8	99.0			
18	Standard Base	5	146.4	18.2	6.7	63.2	100.8	207.3	$40^{\circ}00'$	26.5
	Avg.		146.1	18.4	6.9	62.5	99.9			
19	Binder	5.5	142.5	20.7	8.4	59.4	94.6			
20	Binder	5.5	145.1	19.0	6.4	66.3	95.3	213.8	$45^{\circ}00'$	21.0
	Avg.		143.8	19.8	7.4	62.6	95.0			
21	Modified Base	5.5	148.3	17.2	4.4	74.4	101.9			
22	Modified Base	5.5	146.0	18.6	6.0	67.7	107.1	209.7	$43^{\circ}30'$	23.0
	Avg.		147.1	17.9	5.2	70.9	104.5			
23	Standard Base	5.5	146.1	18.8	6.2	67.0	101.6			
24	Standard Base	5.5	147.6	17.8	5.0	71.9	103.4	207.2	$42^{\circ}15'$	22.5
	Avg.		146.9	18.3	5.6	69.4	102.5			

FIELD OBSERVATIONS

The first three roads given initial treatment of the modified Class I Base were observed by personnel of the Research Laboratory. These roads were: The Princeton-Providence Road (Ky. 293) in Caldwell, Hopkins and Webster Counties; The Fairbanks-Natlee Ky. 330 Road (Ky. 607) in Owen County; and the Willard-Dobbins-Sandy Hook Road (Ky. 486) in Carter and Elliott Counties.

In addition, the three roads which were given an initial treatment of Standard Class I Base during the 1956 construction season were inspected after one year of service. These roads were: the US 41E-US 41A road at the SECL of Hopkinsville in Christian Co.; the Vanceburg-Kinniconick-Mt. Carmel Road (Ky. 24) in Lewis Co.; and the Pine Knot-Holly Hill Road (Ky. 592) in McCreary County.

Locations of all roads observed in this study are shown in Figure 9.

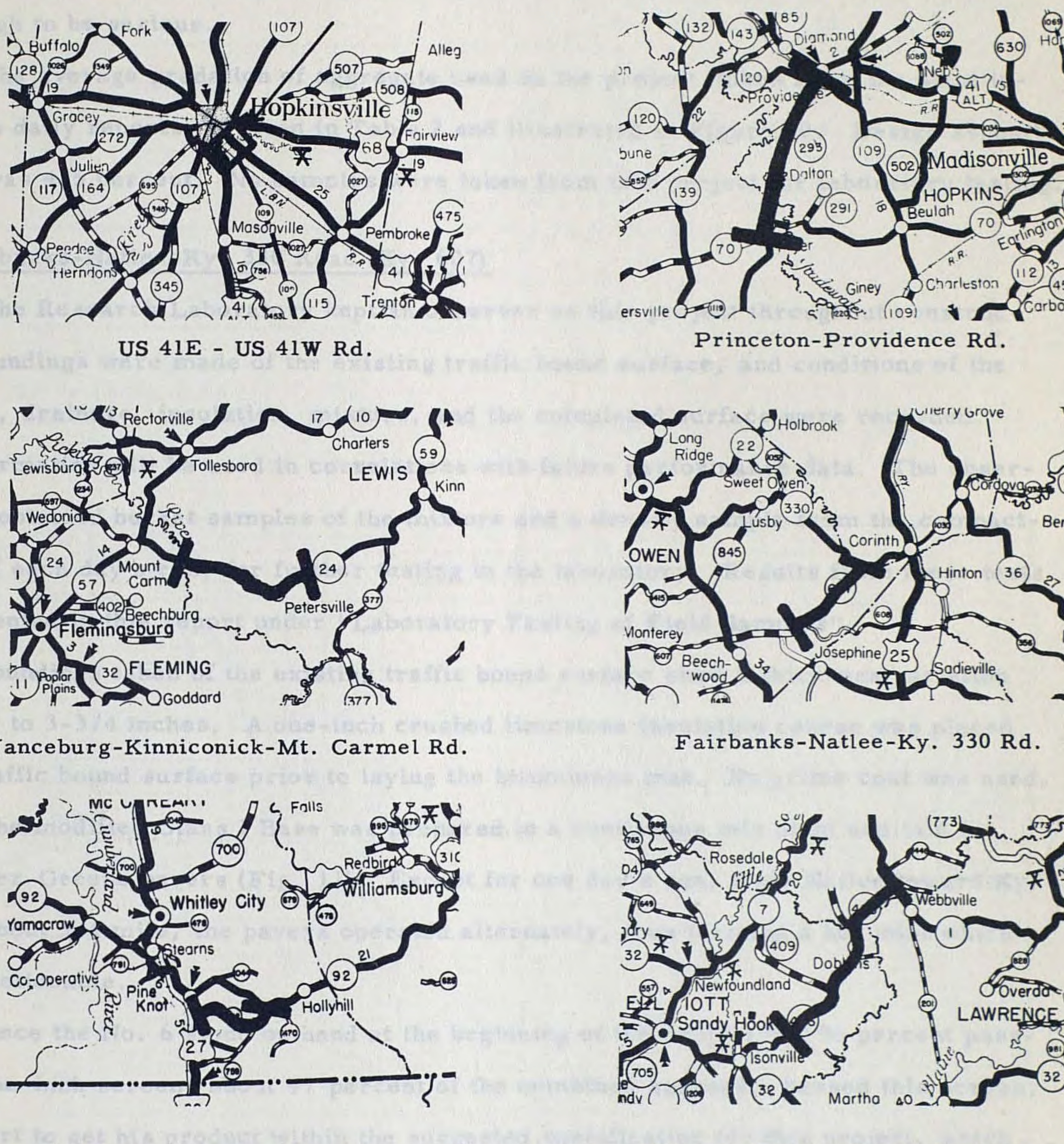
The Princeton-Providence Road (Ky. 293)

Preparation of the subbase on this project consisted of scarifying the existing traffic bound surface and adding 95 lb./yd^2., of crushed limestone (70% No. 610 and 30% No. 10) with compaction by sheepsfoot roller. The bituminous mat was placed directly on the compacted subbase without the use of a prime coat.

The modified Class I Base was prepared in a batch plant and placed by two Barber-Greene pavers. The two pavers were operated alternately, thus forming a hot center joint which was barely noticeable. Compaction was accomplished by the use of one 3-wheel roller and one tandem roller.

Construction personnel reported no trouble with segregation at either the plant or the paver. The material had little tendency to squeeze out under the roller even when rolled at temperatures of 250° to 275°F. immediately behind the paver. However, there was a waving motion in front of the roller wheels which tended to cause the appearance of fine transverse cracks at the pavement surface. Use of a prime coat might

STANDARD CLASS I BASE | MODIFIED CLASS I BASE



US 41E - US 41W Rd. | Princeton-Providence Rd.

Vanceburg-Kinniconick-Mt. Carmel Rd. | Fairbanks-Natlee-Ky. 330 Rd.

Pine Knot-Holly Hill Rd. | Willard-Debbins-Sandy Hook Rd.

Fig. 9: Maps Showing Locations of Roads Observed

have been beneficial in preventing this condition. The surface texture was coarse and rather open with a few slightly segregated spots in evidence, but these were not numerous enough to be serious.

The average gradation of aggregate used on the project (taken from the plant inspector's daily reports) is given in Table 2 and illustrated in Figure 10. Design asphalt content was 4.5 percent. No samples were taken from this project for laboratory testing.

The Fairbanks-Natlee-Ky. 330 Road (Ky. 607)

The Research Laboratory kept an observer on this project throughout construction. Soundings were made of the existing traffic bound surface, and conditions of the subgrade, drainage, insulation, mixture, and the completed surface were recorded. This information will be used in correlations with future performance data. The observer also obtained bucket samples of the mixture and a density sample from the compacted mat of each day's run, for further testing in the laboratory. Results from these tests are presented in this report under "Laboratory Testing of Field Samples".

Soundings taken of the existing traffic bound surface show a thickness variation from one to 3-3/4 inches. A one-inch crushed limestone insulation course was placed on the traffic bound surface prior to laying the bituminous mat. No prime coat was used.

The modified Class I Base was prepared in a continuous mix plant and laid by two Barber-Greene pavers (Fig. 11). Except for one day's run, from Natlee toward Ky. 330 for about 3/4 mile, the pavers operated alternately, thus forming a hot joint which was not noticeable.

Since the No. 6 stone on hand at the beginning of the project had 95 percent passing the one-inch screen, about 97 percent of the combined aggregate passed this screen. In an effort to get his product within the suggested specification for this project, which allowed only 95 percent passing the one-inch screen, the contractor made some coarser stone and used a two-inch scalping screen at both the crusher and the plant. The mixture produced with this stone had less than 100 percent passing the 1-1/2-inch screen and segregated considerably during handling. The contractor was then given permission

TABLE 2

AVERAGE GRADATION OF MODIFIED CLASS I BASE FIELD MIXTURES

Source	Percent Passing St'd Sieves							
	1-1/2"	1"	1/2"	#4	#8	#16	#50	#100
Caldwell-Hopkins-Webster Co.	100	91	60	38	27	19	9.0	3.6
Owen Co.	100	94	65	42	29	18	8.0	4.1
Carter-Elliott Co. Olive Hill Plant	100	92	60	41	31	21	6.0	2.5
Carter-Elliott Co. Little Sandy Plant	100	92	59	37	30	19	4.6	1.0

* Taken from the plant inspector's daily report.

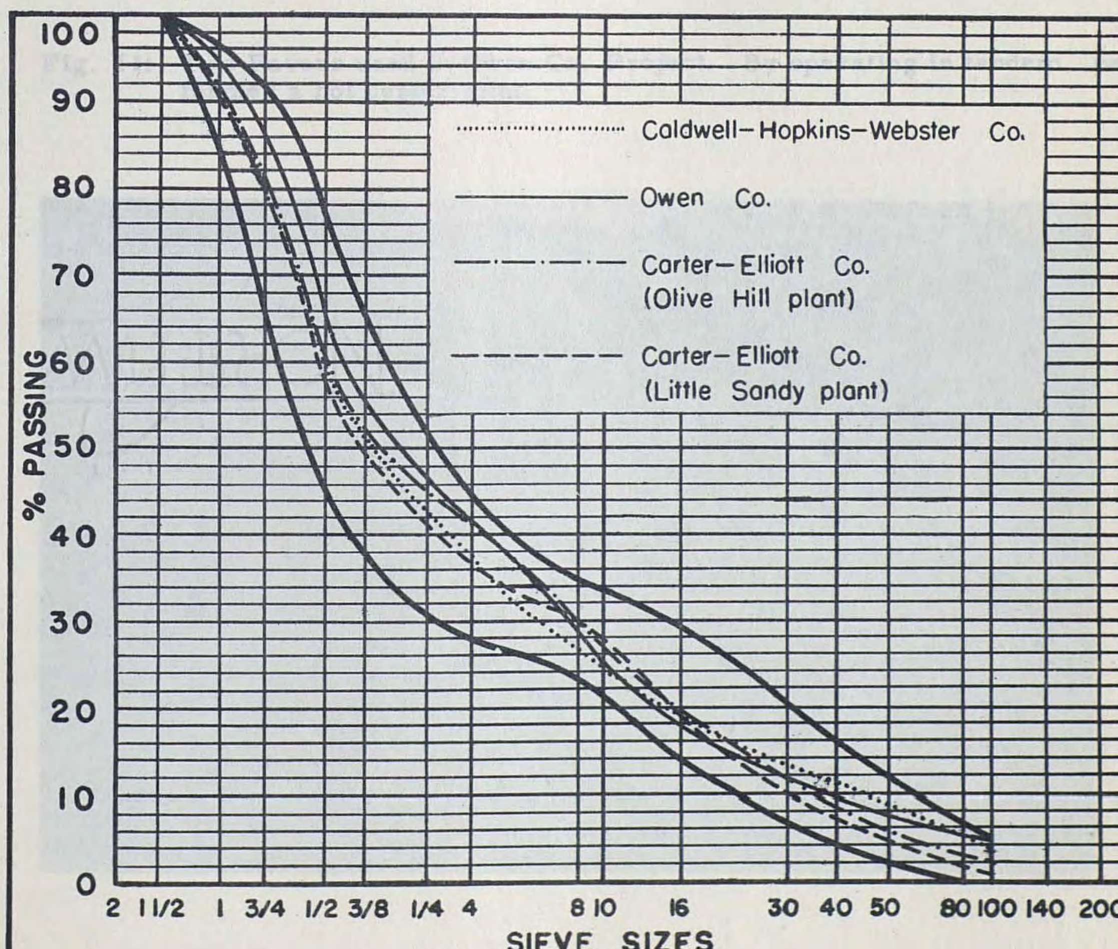


Fig. 10: Average Gradations used on Modified Class I Base Field Projects

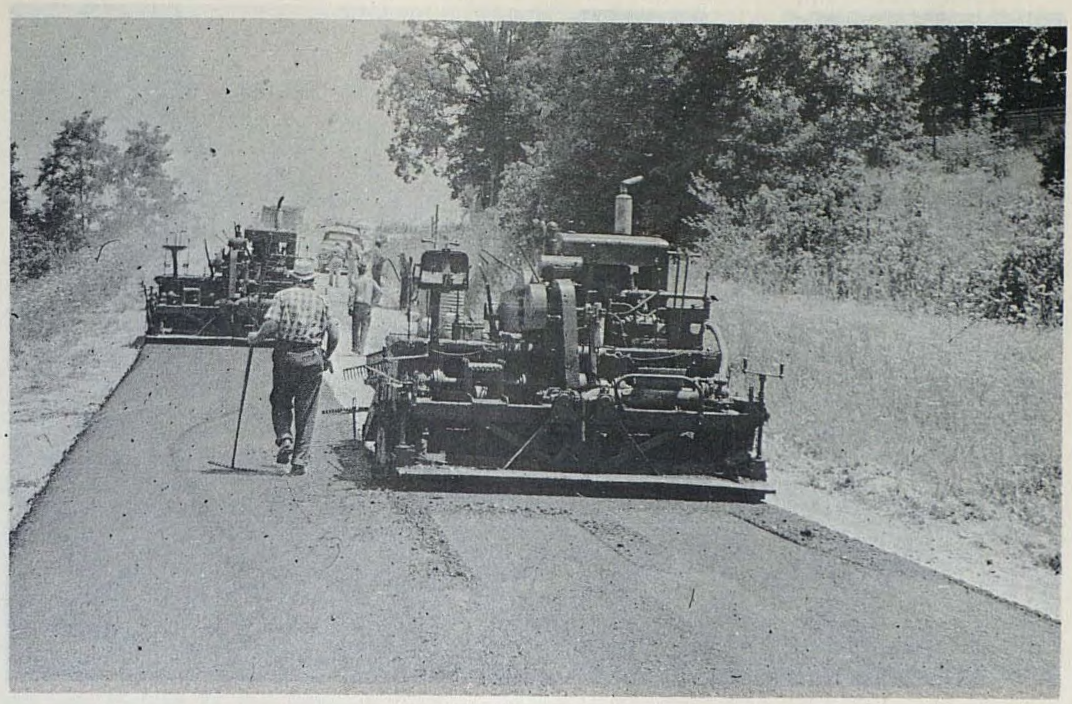


Fig. 11: Two Pavers used in Owen Co. Project. By operating in tandem, pavers formed a hot center joint.

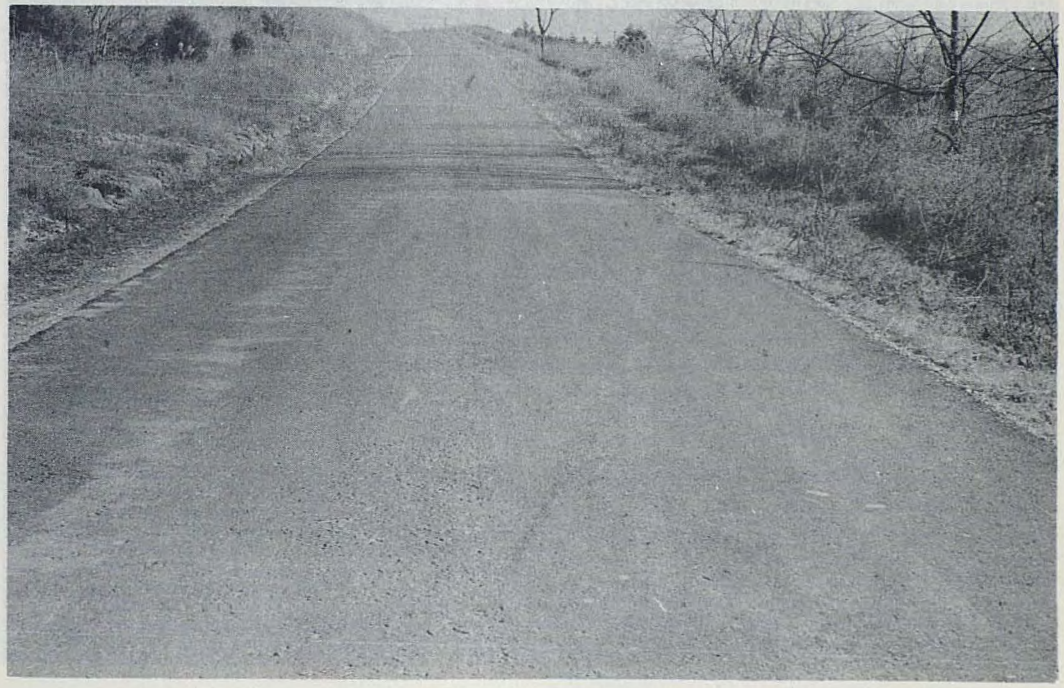


Fig. 12: Portion of Owen Co. Projects where Only One Paver was used, Showing Cold Center Joint.

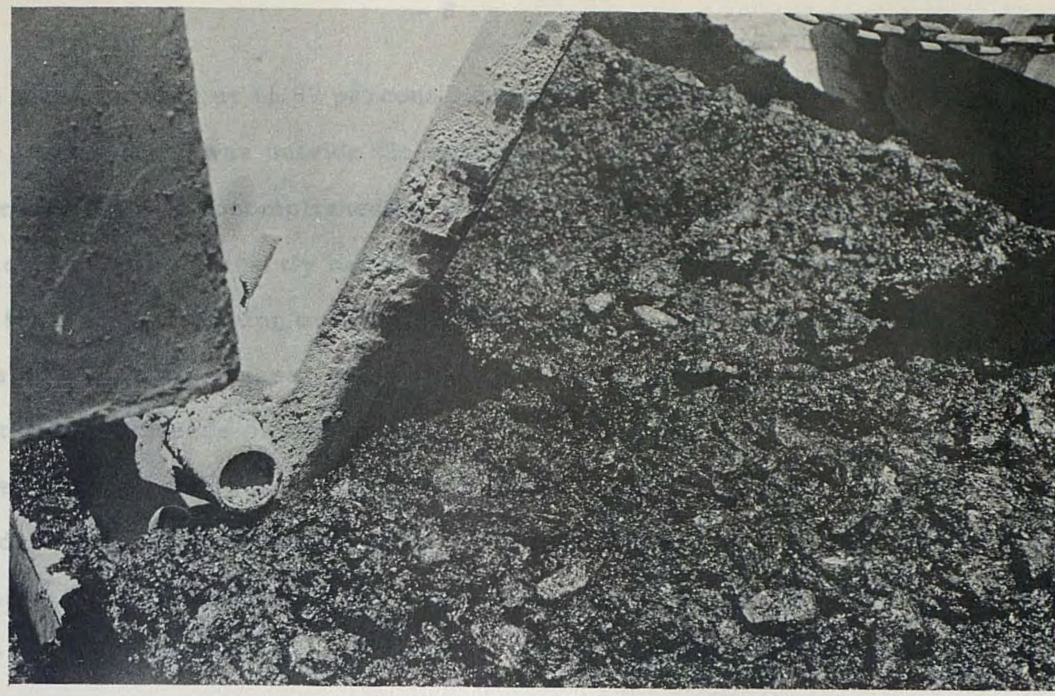


Fig. 13: Modified Class I Base Mixture being Dumped from Truck into Paver

Fig. 14: Typical Texture of Modified Class I Base Surface after 5 Months Service

to produce material with up to 97 percent passing the one-inch screen; and no more of the coarse stone, which was outside the specification for No. 6 stone, was used.

Compaction was accomplished by one 3-wheel roller and one tandem roller. The material could be rolled directly behind the paver without undue displacement; however, some fine transverse cracking occurred from a waving motion under the roller. Except for the one day when the coarser stone was used, the surface had a uniformly medium texture with little evidence of segregation.

The average gradation of aggregate used on the project (taken from the plant inspector's daily reports) is given in Table 2 and illustrated in Figure 10. Design asphalt content was 4.5 percent; while the average asphalt content of density samples was approximately 5 percent by extraction. This value may be slightly high because of a loss of dust from the aggregate to the effluent during extraction.

This road was inspected November 26, 1957, 4-1/2 months after construction. At this time the surface appeared to be well sealed and the fine transverse cracks which developed under the roller were healed. No failures had occurred.

The Willard-Dobbins-Sandy Hook Road (Ky. 486)

Preparation of the roadway before placing the bituminous material consisted of a one-inch course of crushed limestone (No. 6 and No. 10) placed in the conventional manner. No prime coat was used.

Two plants were used to supply the modified base mixture. A batch plant at Olive Hill supplied material for 10.65 miles, and a continuous mix plant at Little Sandy supplied material for the remaining 3.75 miles of the project. The material was laid by Pioneer pavers with one paver handling the material from each plant. The cold joints obtained were quite good. All the material from the Olive Hill plant was rolled with one 3-wheel roller and one tandem roller, but production from the plant at Little Sandy was great enough to require an additional roller. The contractor was given permission to use a self-propelled pneumatic roller (Fig. 15) for this purpose. A great deal of fine transverse cracking appeared during the rolling operation (Fig. 16).

Fig. 15: Pneumatic Roller used on Carter-Elliott Co. Project. Note texture of mix and sharp edge.

Fig. 16: Carter-Elliott Co., Example of Cracking which Developed During Rolling

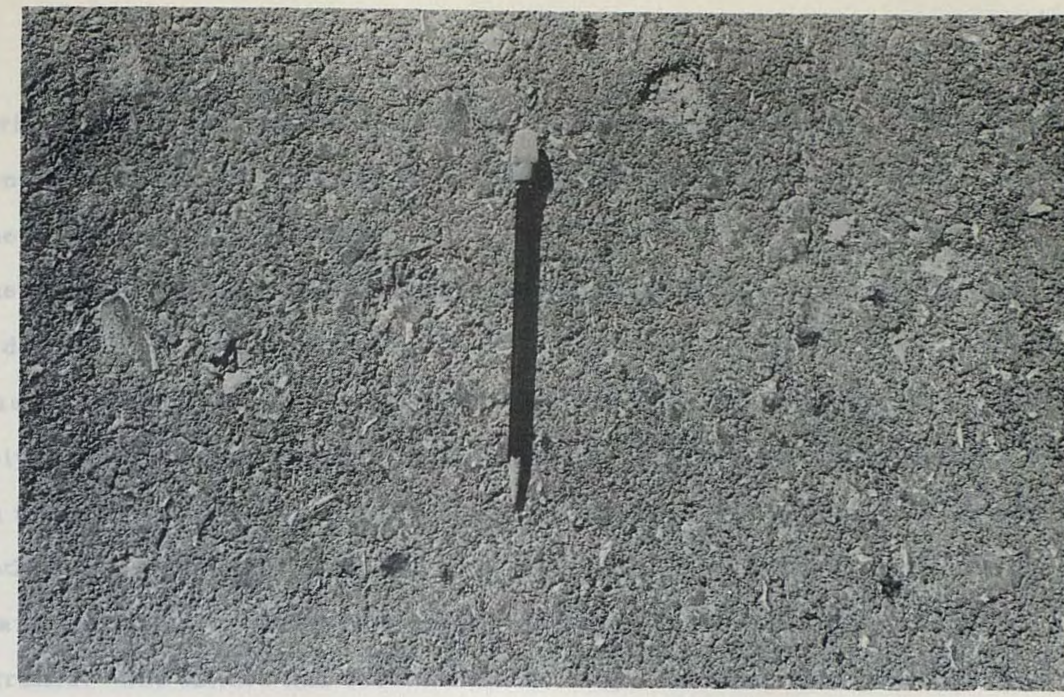


Fig. 17: Carter-Elliott Co., Close-up of Pavement Surface, Showing Typical Fine, Grainy Texture.

Fig. 18: Same Pavement Shown in Fig. 17, Showing Segregation which Occurred in Some Portions of the Project.

Surface texture was medium to fine and had a grainy appearance. The only segregation noticed was in the material from Little Sandy plant which was low in material passing the No. 50 and No. 100 sieves.

The average gradation of aggregate used on the project (taken from the plant inspector's daily report) is given in Table 2 and illustrated in Figure 10. Design Asphalt content was 4.5 percent, while the average asphalt content of density samples was approximately 5 percent by extraction. Again the value of 5 percent may be slightly high.

An inspection was made on this project on November 1, 1957, approximately three months from the time of construction. At this time the pavement presented a very good appearance; virtually all the fine cracks mentioned earlier had been sealed by the action of traffic. One failure had occurred in a side hill cut where the pavement was underlain by a stratum of heavy clay.

US 41E - US 41A Road (SECL Hopkinsville)

An initial treatment of Standard Class I Base was constructed in 1956 and a seal coat applied during the same season. Apparently most of the asphalt used for seal coating had been taken up by surface voids, leaving little on the surface for cementing the aggregate. Voids were probably sealed but aggregate retention was poor. Surface texture before sealing had been very rough and open. One failure approximately 200 feet long in an outside wheel trace near US 41A was noted during an inspection in November, 1957. A general view of this road is given in Figure 19.

Vanceburg-Kinniconick-Mt. Carmel Road (Ky. 24)

Here, a standard Class I Base initial treatment was constructed in 1956, and the entire project was later chip sealed (See Fig. 20) apparently during the 1957 season. No attempt was made to determine the extent of damage prior to sealing, although it must have been considerable. All failures discussed had developed subsequent to sealing.

The first two miles of pavement (starting at the Fleming Co. Line) had 8.3 percent of their total area patched. There was only one patch in the next 1.5 mile, but this

Fig. 19: General View of Christian Co. Project. The surface is Standard Class I Base, with chip seal.

Fig. 20: Lewis Co., Close-up of Surface. Note segregated area of Standard Base showing through chip seal.

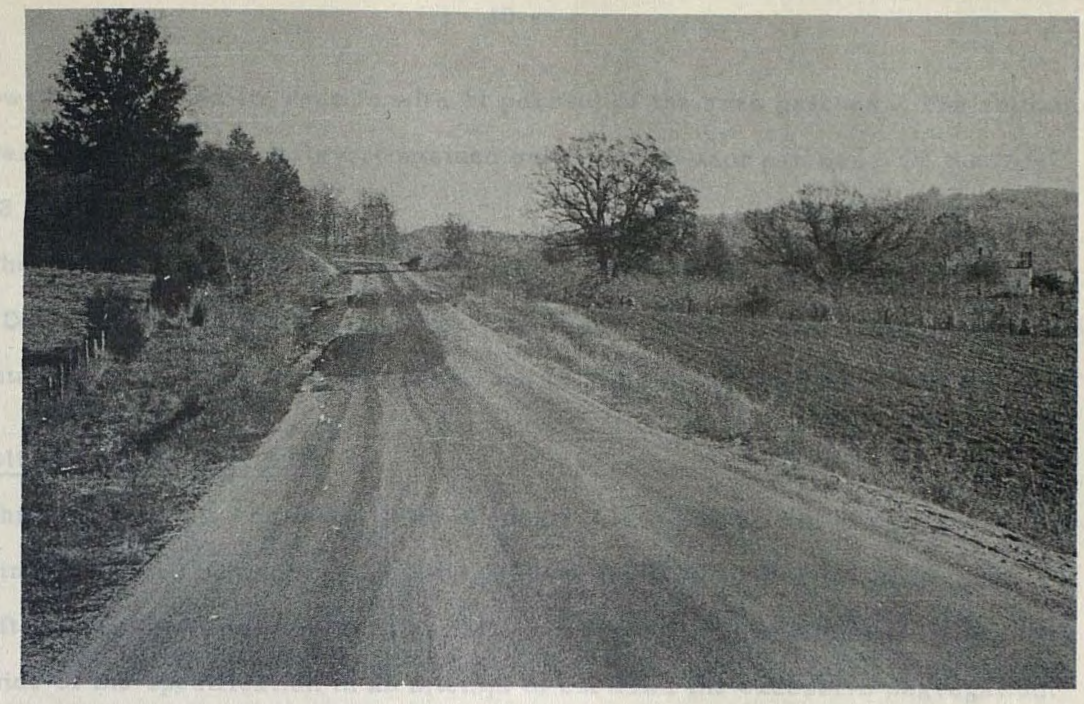


Fig. 21: Lewis Co., Showing Extensive Failure in Small Sidehill Cut

Fig. 22: Lewis Co., Showing Patch Covering Failed Area. Failure was probably due to poor drainage, indicated by obstructed side ditch.

was followed by a 1.65-mile section with 11 percent of the area patched. The remaining 5 miles, which lay in a valley, contained only two 150-foot patches. Of the total area, 3.8 percent had failed.

The two heavily damaged sections were mainly in sidehill cuts on grades in Silurian-Devonian shales, which are notably poor subgrades. These two sections combined contained 36 percent of the total area and had 90 percent of the total failures.

US 27-Holly Hill Road (Ky. 592)

This was the only one of the three Standard Class I Base initial treatments constructed in 1956 which had not been sealed prior to the November 1957 inspection.

After one mile of the project was laid, the aggregate gradation was changed to the fine side of the specification in an attempt to cut down the excessive segregation. This change helped considerably, although segregation remained a problem.

Within this first mile a .15-mile section had been subjected to heavy coal truck traffic and 25 percent of the surface had failed (See Fig. 25). Of the other .85 mile, failure of 1.75 percent of the surface could be attributed to segregated areas, which gave water free access to the subgrade,in conjunction with raveling of the surface. In the same .85 miles another 1.75 percent of the surface had failed from other causes. Another .5 mile laid in similar terrain but with the finer gradation had two percent of the surface failed, none of which could be attributed directly to the material. Of 1.05 miles laid on a hill, three percent of the surface had failed, with most failures occurring in sidehill cuts where the grade intersected clay strata. No failure occurred in the remaining 2.65 miles (slightly more than one-half the total project) which lay along a sandy ridge. The project had two percent of the total surface failed for all reasons. Water penetration and slight raveling had occurred at many segregated areas where the finer gradation was used (Fig. 26) but no major damage was evident.

Fig. 23: Close-up Showing Typical Texture of McCreary Co. Pavement in Places where Segregation did not Occur

Fig. 24: Close-up of McCreary Co. Pavement, Showing Severe Segregation found in Numerous Areas of this Project

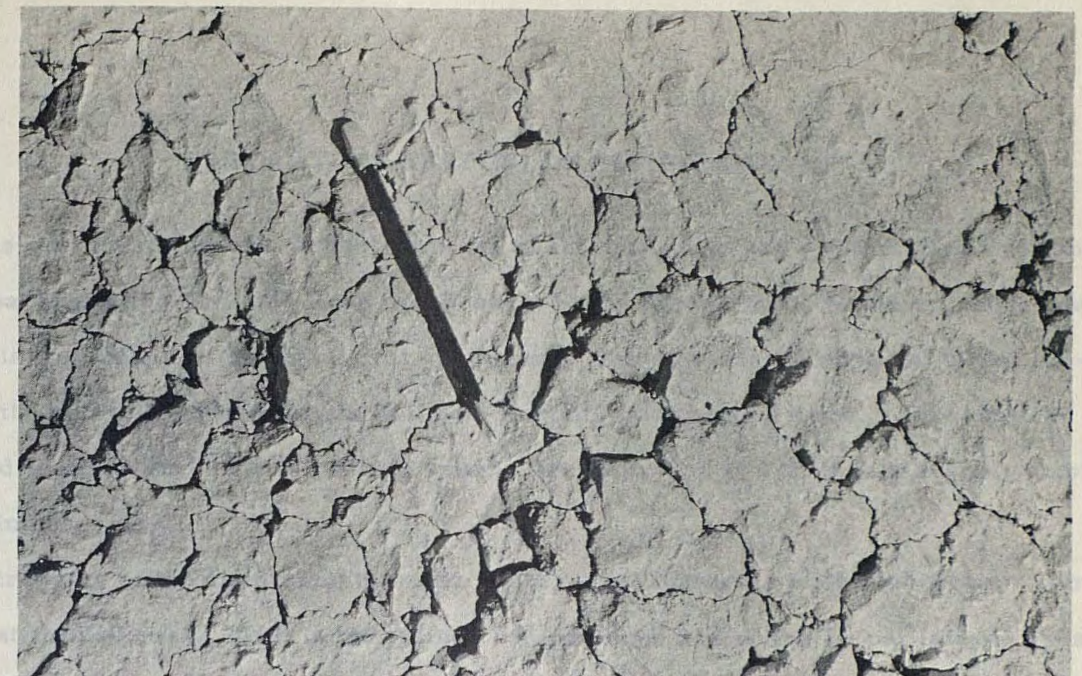


Fig. 25: Close-up of McCreary Co. Pavement, Showing Break-up due to Heavy Coal Truck Traffic

Fig. 26: McCreary Co., Showing Close-up of Lightly Raveled Area where Water had Penetrated to Subgrade

LABORATORY TESTING OF FIELD SAMPLES

As previously stated, bucket samples of the plant mix were obtained daily from the Fairbanks-Natlee-Ky. 330 Road and brought to the laboratory. However, only one sample, large enough to make several specimens, was taken from material being produced at the Olive Hill plant for the Willard-Dobbins-Sandy Hook Road. All samples were used to make six- by twelve-inch triaxial and four- by 2-1/2-inch Marshall stability specimens.

Strengths of the field samples were higher than strengths of the laboratory samples tested previously, both in unconfined compression and under 20 psi lateral pressure. This was at least partially due to the reheating necessary for molding and compacting the field samples. Marshall stabilities of the field samples were quite good and Marshall flow values fell within the desired range(Table 3).

None of the field samples compacted to as high density as the laboratory samples under the same compactive effort, since they contained smaller amounts of fine aggregate. Owen County samples compacted to a greater density than Carter-Elliott samples for the same reason.

In addition to the samples taken for stability determinations, sections were cut from the completed pavements in order to check the densities obtained under field compaction. One sample was cut for each day's run on both the Owen and Carter-Elliott projects.

Field densities on the Owen County job were about equal to densities of laboratory compacted triaxial specimens of the same material, while field densities on the Carter-Elliott project were just slightly lower than those achieved by Marshall compaction of the same material. Marshall compaction produced about 2 percent fewer voids in the compacted aggregate than did the compaction given triaxial specimens (Table 3). Since no material from the Little Sandy Plant, which received pneumatic rolling in the field, was compacted in the laboratory, no comparison can be made with this material.

TABLE. 3

SUMMARY OF DATA FROM LABORATORY COMPACTED FIELD SAMPLES

Sample	Sample Designation	Design Asph. Cont. %	Unit Wt. lb./cu.ft.	Per Cent Voids Agg. Only	Mix	Filled with Asphalt	Compressive Stress Unconfined	20 psi. Restraint	Angle of Friction	Apparent Cohesion psi.	Marshall Stability	Marshall Flow
					Owen Co. Field Samples							
1	Triaxial	4.5	142.4	21.2	9.8	53.8	163.7					
2	Triaxial	4.5	141.5	21.7	10.4	52.1		258.2				
3	Triaxial	4.5	143.9	20.4	8.9	56.4	211.8					
4	Triaxial	4.5	141.9	21.5	10.1	53.0		303.0				
5	Triaxial	4.5	145.3	19.6	8.0	59.2	200.2					
6	Triaxial	4.5	146.3	19.0	7.3	61.6		235.5				
	Avg.	4.5	143.6	20.6	9.1	56.0	192.0	266.0	34°00'	46.5		
1	Marshall	4.5	150.2	16.9	4.9	71.0					1596	13
2	Marshall	4.5	146.8	18.8	7.0	62.8					1403	16
3	Marshall	4.5	147.2	18.6	6.8	63.4					1622	17
	Avg.	4.5	148.1	18.1	6.2	65.7					1540	15
					Carter-Elliott Co. Field Samples							
1	Triaxial	4.5	139.7	20.6	9.4	54.4		251.1				
2	Triaxial	4.5	137.8	21.6	10.6	50.9	125.2					
3	Triaxial	4.5	138.1	21.5	10.4	51.6		276.2				
4	Triaxial	4.5	140.7	20.0	8.7	56.5	181.9					
5	Triaxial	4.5	138.4	21.3	10.2	52.1		244.8				
	Avg.	4.5	138.9	21.0	9.9	53.1	153.0	257.0	42°00'	34.5		
1	Marshall	4.5	148.2	15.7	3.8	75.8					2827	16
2	Marshall	4.5	145.5	17.3	5.6	67.6					2273	16
3	Marshall	4.5	147.5	16.1	4.3	73.3					2220	16
4	Marshall	4.5	142.3	19.1	7.7	59.7					1695	13
5	Marshall	4.5	145.1	17.5	5.9	66.3					2380	12
6	Marshall	4.5	140.7	20.0	8.7	56.5					1744	13
7	Marshall	4.5	141.0	19.8	8.5	57.1					1793	16
8	Marshall	4.5	139.5	20.7	9.5	54.1					1801	21
	Avg.	4.5	143.7	18.3	6.8	63.8					2091	15

As stated previously, all material from the Little Sandy plant used on the Carter-Elliott project was compacted by a pneumatic roller. This section of the project averaged 0.8 percent more voids in the compacted aggregate than did the section laid without pneumatic rolling, with material from the Olive Hill plant (Table 4). However, the difference here should be attributed to gradation rather than compactive effort, since aggregate from the Little Sandy plant was very low in material passing the No. 50 and No. 100 sieves. Apparently the pneumatic roller used was too light to increase materially the density of these pavements beyond the values obtained by normal compaction.

TABLE 4

SUMMARY OF DATA ON DENSITY SAMPLES CUT FROM THE PAVEMENT

Sample No.	Date Laid	Asphalt Content By Design	Asphalt Content By Extraction	Unit Wt. lb./cu. ft.	Per Cent Voids Agg. Only	Per Cent Voids Mix	Per Cent Voids Filled with Asphalt
			Owen County Field Density Samples				
1	6 - 19	4.5	5.8	143.4	20.7	9.2	55.6
2*	6 - 20	4.5	--	153.5	15.1	2.8	81.5
3	6 - 25	4.5	--	142.6	21.1	9.7	54.0
4	6 - 26	4.5	5.0	150.3	16.8	4.8	71.4
5	6 - 27	4.5	4.6	141.6	21.7	10.4	52.1
6	6 - 28	4.5	4.7	141.8	21.7	10.3	52.5
7	7 - 1	4.5	5.0	145.3	19.6	8.0	59.2
8	7 - 2	4.5	4.3	144.3	20.2	8.6	57.4
9	7 - 3	4.5	4.7	143.2	20.8	9.3	55.3
10	7 - 5	4.5	5.2	146.2	19.2	7.5	60.9
11	7 - 6	4.5	4.9	139.9	22.6	11.4	49.6
	Avg.	4.5	4.9	143.9	20.4	8.9	56.8
			Carter-Elliott Co. Field Density Samples (Olive Hill Plant)				
1	5 - 21	4.5	4.8	147.0	16.3	4.5	72.4
2	5 - 25	4.5	4.6	139.7	20.5	9.3	54.6
3	6 - 1	4.5	4.9	143.7	18.4	6.9	62.5
4	6 - 6	4.5	5.3	143.6	18.4	6.9	62.5
5	7 - 17	4.5	5.0	138.0	21.6	10.5	51.4
6	7 - 23	4.5	5.0	140.9	19.8	8.5	57.1
7A	7 - 24	4.5	5.6	143.4	18.4	6.9	62.5
8A	7 - 25	4.5	4.8	143.3	18.4	6.9	62.5
9A	7 - 26	4.5	5.0	142.1	19.1	7.7	59.7
10A	7 - 29	4.5	5.5	145.7	17.4	5.7	67.2
11A*	7 - 30	4.5	4.7	150.8	14.1	2.0	85.8
	Avg.	4.5	5.0	142.7	18.8	7.4	61.2
			Carter-Elliott Co. Field Density Samples (Little Sandy Plant - Pneumatic Rolling)				
7	7 - 24	4.5	5.3	143.2	18.8	7.3	61.2
8	7 - 25	4.5	4.1	141.2	19.8	8.5	57.1
9	7 - 26	4.5	5.2	139.9	20.5	9.3	54.6
10	7 - 29	4.5	4.9	142.5	19.1	7.7	59.7
11	7 - 30	4.5	4.7	139.5	20.5	9.3	54.6
12	7 - 31	4.5	4.7	143.4	18.4	6.9	62.5
13	8 - 1	4.5	4.9	141.8	19.5	8.1	58.5
14	8 - 6	4.5	5.2	140.3	20.2	8.9	55.9
	Avg.	4.5	4.9	141.5	19.6	8.3	58.0

* Not included in averages

SUMMARY AND CONCLUSIONS

The modified Class I Base mixture thus far has proved more satisfactory as an initial treatment than the Standard mixture. The preliminary laboratory studies indicated that it had ample stability, could be compacted to a voids content of six to eight percent -- considered adequate for the compactive effort used -- and was not overly sensitive to asphalt content. The construction projects showed the material easily workable, stable under compaction, and almost free of the troublesome segregation often encountered with the Standard Class I Base mixture.

Because of their low dust contents, the field mixtures tested had higher void contents than the mixtures made in the laboratory. Low void contents provide greater resistance to weathering as well as preventing the access of water to the subgrade. Most of the field mixtures tested contained somewhat more than the indicated optimum amount of asphalt. The richer mixtures would, however, seem to be desireable when the material is to be used for initial treatments. As long as stability is adequate and enough voids are left to prevent bleeding, the additional asphalt should impart greater durability and imperviousness to the pavement.

Of the three roads given an initial treatment of Standard Class I Base in 1956, two had a number of failures. It was noted, however, that virtually all the failed areas were in relatively short sections of the road -- mainly in sidehill cuts, on hills, and with soils of low bearing value, in some cases aggravated by poor drainage.

Most of the failed areas were in the outside wheel tracks in these sections, probably because of the fact that most traffic bound roads, having their greatest thickness near the center, feather out to practically zero thickness at the edges. These edges receive little compaction from traffic, and consequently the bituminous mat is poorly supported in the outside wheel tracks as the traffic lanes are shifted towards the edge.

It should be noted that failures in these weaker areas make for high maintenance costs and do irreparable damage to the base and subgrade. While it may not be economically feasible, or even desireable, to design for a condition of no failure, a great many of such failed areas could be prevented. This could be done in many cases merely by reworking or redistributing the existing base material and by providing additional granular material. Probably the first operation required would be scarifying, reshaping, and recompacting the existing traffic bound surface to provide uniformity of section, distribution and compaction. The additional granular material required could be applied and blended during the scarifying and reshaping of the existing material to form a granular stabilized base, or it could be placed on the recompacted traffic bound surface as a granular base course.

The new base mixture has several features which suggest the possibility of its serving in place of both base and binder in high-type construction, thereby eliminating the need for any distinction between base and binder mixes. As a further future possibility, the surface texture of the mixture appears amenable to light sand-asphalt surfacing.

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